12-1-2008

Bovine Babesiosis

Iowa State University Center for Food Security and Public Health

Bovine Babesiosis

Tick Fever,
Cattle Fever,
Texas Fever,
Piroplasmosis,
Redwater

Last Updated: December 2008

Importance

Bovine babesiosis is a tick-borne, parasitic infection that causes significant morbidity and mortality in cattle. It is the most important arthropod-borne disease of cattle worldwide. The most prevalent species, *Babesia bovis* and *B. bigemina*, are found throughout most tropical and subtropical regions,. The economic losses from these two organisms can be considerable, particularly in developing countries. Although babesiosis can be controlled with vaccination and treated with antiparasitic drugs, the vaccines are live and have safety concerns, and many effective drugs have been withdrawn from the market due to safety or residue problems. *B. bovis* and *B. bigemina* were once endemic in the southern United States, and caused severe losses to the cattle industry. Although these organisms and their vectors were eradicated from the U.S. by 1943, reintroduction is a significant threat. Another important species, *B. divergens*, causes losses to farmers in parts of Europe and is a serious zoonotic threat to people who are immunocompromised.

Etiology

Babesiosis results from infection by protozoa in the genus *Babesia* (family Babesiidae, order Piroplasmida). The three species found most often in cattle are *Babesia bovis, B. bigemina* and *B. divergens*. Additional species that can infect cattle include *B. major*, *B. ovata*, *B. occultans* and *B. jakimovi*.

Organisms that are very closely related to *B. divergens*, but do not seem to affect cattle, have recently been discovered in wildlife and humans. Whether these species should be called *B. divergens* is uncertain, but at least in some cases, they appear to be distinct organisms. Some, such as *Babesia venatorum*, have been given individual names.

Species Affected

B. bovis and *B bigemina* are found in cattle, which are the main reservoir hosts. They also affect water buffalo (*Bubalus bubalis*) and African buffalo (*Syncerus caffer*). *B bovis* and *B. bigemina* were recently discovered in white-tailed deer (*Odocoileus virginianus)* in Mexico. The importance of this finding is unknown, but animals other than cattle have generally been considered of little epidemiological significance as reservoir hosts.

B. divergens causes clinical signs in cattle and reindeer (*Rangifer tarandus*). Mongolian gerbils (*Meriones unguiculatus*) can be experimentally infected, but mice, hamsters, rats and rabbits are resistant. Splenectomized humans and non-human primates (including chimpanzees and rhesus monkeys) are highly susceptible to *B. divergens* and become severely ill, but non-splenectomized primates are resistant. Experimental infections can also be established in splenectomized ungulates including mouflon (*Ovis musimon*), red deer (*Cervus elaphus*), roe deer (*Capreolus capreolus*), and fallow deer (*Dama dama*) but clinical signs are not usually seen. Very low and transient parasitemia has been reported in splenectomized sheep. Intact animals of these species are resistant.

B. jakimovi can infect cattle, roe deer, Asian elk (*Alces alces*), and reindeer. *B. major*, *B. ovata* and *B. occultans* infect cattle.

Geographic Distribution

Bovine babesiosis can be found wherever the tick vectors exist, but it is most common in tropical and subtropical areas. *B. bovis* and *B. bigemina* are particularly important in Asia, Africa, Central and South America, parts of southern Europe, and Australia. Although *B. bovis* is usually found in the same general geographic area as *B. bigemina*, slightly different groups of ticks spread these two species and some differences in their distribution can be seen. For example, *B. bigemina* is more widely distributed than *B. bovis* in Africa. *B. bigemina* and *B. bovis* and their vectors were formerly enzootic throughout much of the southern United States, but now are found only in a quarantine buffer zone along the Mexican border.

the Center for Food Security & Public Health
Iowa State University®
College of Veterinary Medicine
Iowa State University
Ames, Iowa 50011
Phone: 515.294.7189
Fax: 515.294.8259
cfsph@iastate.edu
www.cfsph.iastate.edu

Institute for International Cooperation in Animal Biologics
Iowa State University
College of Veterinary Medicine
www.cfsph.iastate.edu/IICAB/

B. divergens is an important parasite in parts of Europe including the United Kingdom, Spain and northern Europe. Surveys have found evidence for this species throughout Europe, and it may also occur in North Africa. Its vector, *I. ricinus*, can survive from northern Scandinavia to the Mediterranean. However, because this tick requires 80% humidity, it can be found only in some microenvironments such as the base of vegetation in forests, rough hill scrub, and damp low-lying land. *B. major* can be found in parts of Europe, Northwest Africa and Asia, as well as China. *B. ovata* has been described in Japan, China and other parts of eastern Asia. *B. occultans* has been reported in Africa, and *B. jakimovi* occurs in Siberia.

Transmission

Babesia species are transmitted by ticks, which become infected when they ingest parasites in the blood of infected cattle. The major vectors for *B. bigemia* are *Rhipicephalus microplus* (formerly *Boophilus microplus*) and *R. annulatus* (formerly *Boophilus annulatus*). *R. decoloratus*, *R. geigyi*, and *R. evert*si can also transmit this species. The major vectors for *B. bovis* are *R. microplus* and *R. annulatus*, but *R. geigyi* can also be a vector. *B. divergens* is transmitted mainly by *Ixodes ricinus. B jakimovi* may also be transmitted by an *Ixodes* species. *Haemaphysalis punctata* transmits *B. major*, *Haemaphysalis longicornis* transmits *B. ovata*, and *Hyalomma marginatum* transmits *B. occultans*.

Inside the tick, *Babesia* zygotes multiply as 'vermicules,' which invade many of the tick's organs including the ovaries; *Babesia* species are readily passed to the next generation of ticks in the egg. These parasites can sometimes be passed transovarially though several generations, although this varies with the species of *Babesia* and the species of tick. *B. divergens* can survive in tick populations for at least 4 years even if cattle are not present. When an infected tick attaches to a new host, *Babesia* are stimulated to undergo their final maturation. *B. bovis* parasites usually become infective within 2-3 days after larval ticks attach, and can be transmitted by larvae. In *R. microplus*, *B. bovis* does not persist after the larval stage. In contrast, *B. bigemina* matures in approximately 9 days after a larval tick attaches, and it is only transmitted by nymphs and adults. All three stages of *I. ricinus* can transmit *B. divergens*.

Babesia species can also be transmitted between animals by direct inoculation of blood. Biting flies and fomites contaminated by infected blood might act as mechanical vectors, although this method of transmission is thought to be of minor importance.

Babesia are maintained in cattle populations by asymptomatic carriers that have recovered from acute disease. *B. bovis* persists in cattle for years, and *B bigemina* survives for a few months. Recrudescence of parasitemia can occur at irregular intervals. Calves can be infected *in utero*; however, this appears to require pathological changes in the placenta, and transplacental infection seems to be accidental and rare.

Incubation Period

The symptoms of *B. bigemina* and *B. bovis* infections usually appear 2 to 3 weeks after tick infestation.. After direct inoculation of blood, the incubation period can be as short as 4 to 5 days for *B. bigemina* and 10 to 12 days for *B. bovis*.

Clinical Signs

The clinical signs vary with the age of the animal and the species and strain of the parasite. Most cases of babesiosis are seen in adults; animals younger than 9 months usually remain asymptomatic. Strains vary considerably in pathogenicity; however, *B. bovis* is usually more virulent than *B. bigemina* or *B. divergens.*

Typically, animals infected with *B. bigemin*a develop anorexia and a high fever; fever may be present before other clinical signs appear. The characteristic signs are caused by hemolysis and anemia. Animals become inappetent, may separate from the herd, and are weak, depressed and reluctant to move. The mucous membranes become pale, and respiration and heart rate increase. Anemia often develops rapidly, and is frequently accompanied by hemoglobinuria and hemoglobinemia. Jaundice occurs mainly in subacute cases. Diarrhea or constipation may also been seen, and a respiratory distress syndrome with dyspnea can develop in severely affected animals. Fever may cause abortion in pregnant cows, and bulls sometimes have a temporary decrease in fertility. Central nervous system (CNS) signs are uncommon in *B. bigemina* infections. Some cattle usually die, but in animals that survive, the anemic crisis generally passes within a week. The survivors may be weak and in reduced condition, although they usually recover fully. Subacute infections, with less apparent clinical signs, are also seen.

B. bovis infections are similar but are often more severe. However, hemoglobinuria and hemoglobinemia are less common than in animals infected with *B. bigemina*. In addition, infected erythrocytes can be sequestered in brain capillaries, resulting in neurologic signs such as incoordination, teeth grinding and mania. Some cattle may be found on the ground with the involuntary movements of the legs. Most animals with CNS signs die.

B. divergens infections can be mild to severe, depending on the strain and other factors. Subclinical infections, with mild fever, anorexia and an uneventful recovery, are common; more severe cases resembling *B. bigemina* infections can also be seen. CNS signs are rare in *B. divergens* infections, but may occur if the anemia causes brain anoxia. *B. major* is nonpathogenic under most conditions, and *B. ovata* is mildly pathogenic.

Intrauterine infection with *Babesia* may result in the birth of a febrile, weak, anemic, icteric and dehydrated calf which may have convulsions or other neurologic signs. In one recent case, an affected calf was born to a dam with no history of clinical babesiosis. Intrauterine infections are very rare.

Post Mortem Lesions

Click to view images

Post–mortem lesions are mainly related to intravascular hemolysis, anemia and jaundice. The mucous membranes are usually pale and may be icteric, and the blood can appear thin and watery. Icterus may also be present in the omentum, abdominal fat and subcutaneous tissues. The spleen is markedly enlarged with a dark, pulpy, friable consistency. The liver may be enlarged and darkened or icteric, with a distended gallbladder containing thick, granular bile. The kidneys are usually dark red or black, and the urinary bladder often contains reddish–brown urine; however, in some cases, the urine may be normal. The lungs occasionally show signs of pulmonary edema. Other organs including the heart and brain may have petechiae or ecchymoses or be congested, and the surface of the brain can look pink.

Morbidity and Mortality

The morbidity and mortality rates are highly variable. Treatment and previous exposure/ vaccination, as well as the species and strain of parasite, can affect the outcome. Cattle can develop lifelong resistance to a species after infection. Some degree of protection against other *Babesia* species may also be seen. In endemic areas where tick transmission is high year round, animals tend to become infected when they are young, do not become ill, and become immune. This endemic stability can be upset and outbreaks can occur if climate changes, acaricide treatment or other factors decrease tick numbers and animals do not become infected during the critical early period. Outbreaks are also seen in areas where cold seasons interrupt tick-borne transmission for a time, as well as when susceptible animals are introduced to endemic regions or infected ticks enter new areas.

In naive cattle, susceptibility to disease varies with the breed. *B. indicus* cattle and *B. indicus* / *B. taurus* crosses are more resistant than *B. taurus*. Recently, variable susceptibility to *B. bovis* was also reported in some *Bos taurus* cattle: approximately 28% of a population of adult animals was susceptible to infection but resistant to clinical signs. In fully susceptible breeds, up to half or more of untreated adults and up to 10% of treated adults may die. Once hemoglobinuria develops, the prognosis is guarded. Infections with *B. bovis* are generally more likely to be fatal than infections with *B. bigemina* or *B. divergens*, and CNS signs suggest a poor prognosis.

Diagnosis

Clinical

Babesiosis should be suspected in cattle with fever, anemia, jaundice and hemoglobinuria.

Differential diagnosis

Babesiosis resembles other conditions that cause fever, and hemolytic anemia. The differential diagnosis includes anaplasmosis, trypanosomiasis, theileriosis, bacillary hemoglobinuria, leptospirosis, eperythro-zoonosis, rapeseed poisoning and chronic copper poisoning. Rabies and other encephalitides may also be considerations in cattle with CNS signs.

Laboratory tests

Babesiosis can be diagnosed by identification of the parasites in blood or tissues, polymerase chain reaction assays (PCR), serology, or transmission experiments.

In blood and tissues, parasites are found most easily during acute infections. They may be difficult to detect in carriers. Treatment can also clear *Babesia* rapidly from the circulation, although the animal remains ill from their effects. Thick films can be helpful in detecting small numbers of parasites, but species identification is best in thin films. *Babesia* can be identified under oil immersion (minimum x8 eyepiece and x60 objective lens) in stained blood and tissue smears. Giemsa or acridine orange is often used for staining. Immunofluorescent and immunoperoxidase labeling have also been described. These parasites are found within RBCs, and all divisional stages - ring (annular) stages, pear-shaped (pyriform) trophozoites either singly or in pairs; and filamentous or amorphous shapes – can be found simultaneously. Filamentous or amorphous forms are usually seen in animals with very high levels of parasitemia. *B. bovis* trophozoites are small (usually 1–1.5 µm x 0.5–1.0 µm), often paired and usually centrally located in RBCs. *B. divergens* resembles *B. bovis*, but the pairs are often found at the edge of the RBC. *B. bigemina* is much longer (3–3.5 µm x 1–1.5 µm) and can fill the RBC. Morphological variability may make precise species identification difficult.

Polymerase chain reaction (PCR) assays can detect and differentiate *Babesia* species, and are particularly useful in carriers. PCR-enzyme-linked immunosorbent assay (ELISA) has been described. Carriers may also be diagnosed with *in vitro* culture. These animals may occasionally be identified by transfusing blood into a test calf or, in the case of *B. divergens*, Mongolian gerbils (*Meriones unguiculatus*). Animal transmission techniques are cumbersome and seldom used for routine diagnosis.

Serology can detect infected animals; it is most often used for surveillance and export certification. Antibodies to *Babesia* are usually detected with an indirect fluorescent antibody (IFA) test or enzyme-linked immunosorbent assay (ELISA). Complement fixation has also been used, and agglutination assays (latex and card agglutination tests) have been described. Serological cross-reactions can complicate the differentiation of some species in serological tests.

Samples to collect (check also under lab tests)

Before collecting or sending any samples from animals with a suspected foreign animal disease, the proper authorities should be contacted. Samples should

only be sent under secure conditions and to authorized laboratories to prevent the spread of the disease. *B. divergens* and possibly *B. bovis* have been implicated in rare human infections; samples should be collected and handled with all appropriate precautions.

Babesia can be found in blood and tissues. Both thin blood films and organ smears should be taken at necropsy. Preferred tissues include brain (cerebral cortex), kidney, liver, spleen and bone marrow. Some sources also suggest heart muscle. Diagnosis is unreliable in animals that have been dead for more than 24 hours; however, parasites can sometimes be found after this time in blood from the lower leg. For good stain definition, blood films should be stained as soon as possible. Slides should be air-dried, fixed in absolute methanol (5 minutes for organ smears, 1 minute for thin blood smears), and stained for 20-30 minutes with 10% Giemsa.

Thick and thin blood films should be taken from live animals. Whenever possible, blood should be taken from the capillaries in the ear or tail; *B. bovis* is much easier to find in capillary blood than in the general circulation. *B. bigemina* and *B. divergens* can be found throughout the vasculature. Thin blood films should be stained as described above. Thick blood films are not fixed before staining, which allows the RBCs to be lysed and the parasites to be concentrated. These films should be air-dried, heat –fixed at 80°C for 5 minutes, and stained with 10% Giemsa for 15-20 minutes. If samples of capillary blood are not available, jugular blood may be collected into an anticoagulant. EDTA can be used; however, heparin can affect staining and is not recommended. Blood samples should be kept cool, preferably at 5°C, and whenever possible should be delivered to the laboratory within a few hours.

Serum can be collected for serology.

Recommended actions if bovine babesiosis is suspected

Notification of authorities

Bovine babesiosis must be reported immediately to state or federal authorities.

Federal: Area Veterinarians in Charge (AVIC):

www.aphis.usda.gov/animal_health/area_offices/

State Veterinarians:

www.usaha.org/Portals/6/StateAnimalHealthOfficials.pdf

Control

Babesiosis can be eradicated by eliminating the host tick(s). In the U.S., this was accomplished by treating all cattle every 2 to 3 weeks with acaricides. In countries where eradication is not feasible, tick control can reduce the incidence of disease. The development of resistance to acaricides can be a concern. Environmental modification can also destroy tick habitats, but in some cases this may be difficult and/ or ecologically undesirable.

Live, attenuated strains of *B. bovis*, *B. bigemina* or *B. divergens* are used to vaccinate cattle in some countries. These vaccines have safety issues including the potential for virulence in adult animals, possible contamination with other pathogens, and hypersensitivity reactions to blood proteins. They are best used in animals less than a year of age to minimize the chance of disease. In some cases, vaccination of older cattle is necessary (e.g., if susceptible cattle are moved into an endemic area). Older animals should be monitored closely after vaccination, and treated if clinical signs develop. In some countries, animals may be vaccinated in the face of an outbreak. The use of genetically resistant cattle such as *B. indicus* can also decrease the incidence of disease. Natural endemic stability is unreliable as the sole control strategy, as it can be affected by climate, host factors and management.

In endemic areas, sick animals should be treated as soon as possible with an antiparasitic drug. Treatment is most likely to be successful if the disease is diagnosed early; it may fail if the animal has been weakened by anemia. A number of drugs are reported to be effective against *Babesia*, but many of them have been withdrawn due to safety or residue concerns. High doses can eliminate parasites from carrier animals as well as control clinical signs. Blood transfusions and other supportive therapy may also be necessary. Chemoprophylaxis with one drug (imidocarb) can protect animals from clinical disease while allowing the development of immunity. However, there are concerns about residues in milk and meat, and this drug is not available in all countries.

Disinfectants and sanitation are not generally effective against the spread of babesiosis, but care should be taken not to transfer blood from one animal to another.

Public Health

Although some species of *Babesia* such as *B. microti* can affect healthy people, cattle parasites seem to cause disease only in people who are immunocompromised. *B. divergens* causes serious disease in humans who have had splenectomies. This infection is rare; in Europe, approximately 30 cases had been reported as of 2003. It is characterized by the acute onset of severe hemolysis, hemoglobinuria, jaundice, persistent high fever, chills and sweats, headache, myalgia, lumbar and abdominal pain, and sometimes vomiting and diarrhea. Shock and renal failure may also be seen. *B. divergens* infections in humans are medical emergencies. They usually progress very rapidly, and most cases in the past ended in death within a week. With modern, antiparasitic drugs and supportive therapy, the case fatality rate is approximately 40%. Mild cases may resolve with drug treatment alone. To prevent infection with *B. divergens*, immunocompromised individuals should be careful when visiting regions where babesiosis is endemic, especially during the tick season. Exposure to ticks should be prevented by wearing appropriate clothing (e.g., long-sleeved shirts and long pants) and tick repellents.

Skin and clothing should be inspected for ticks after being outdoors, and any ticks found should be removed. There is no definitive evidence that *B. divergens* can infect immunocompetent individuals, or those who are immunosuppressed but not splenectomized. However, antibodies to *Babesia* were found in two of 190 French blood donors.

B. bovis may also be zoonotic, but this is uncertain. At least some historical cases attributed to *B. bovis* were probably caused by *B. divergens*.

For More Information

Food and Agriculture Organization of the United Nations. Manual for the Recognition of Exotic Diseases of Livestock: http://www.spc.int/rahs/

Queensland Department of Primary Industries and Fisheries (DPIF). Making Blood Smears for Tick Fever Diagnosis http://www.dpi.qld.gov.au/cps/rde/dpi/hs.xsl/4790_6241_ENA_HTML.htm

Queensland DPIF. How to Make Organ Smears for Tick Fever Diagnosis http://www.dpi.qld.gov.au/cps/rde/dpi/hs.xsl/4790_6224_ENA_HTML

The Merck Veterinary Manual http://www.merckvetmanual.com/mvm/index.jsp

United States Animal Health Association. Foreign Animal Diseases http://www.aphis.usda.gov/emergency_response/downloads/nahems/fad.pdf

World Organization for Animal Health (OIE) http://www.oie.int

OIE Manual of Diagnostic Tests and Vaccines for Terrestrial Animals http://www.oie.int/international-standard-setting/terrestrial-manual/access-online/

OIE Terrestrial Animal Health Code http://www.oie.int/international-standard-setting/terrestrial-code/access-online/

References

Acha PN, Szyfres B [Pan American Health Organization (PAHO)]. Zoonoses and communicable diseases common to man and animals. Volume 3. Parasitoses. 3rd ed. Washington DC: PAHO; 2003. Scientific and Technical Publication No. 580. Babesiosis; p. 15-20.

Allsopp MT, Allsopp BA. Molecular sequence evidence for the reclassification of some *Babesia* species. Ann N Y Acad Sci. 2006;1081:509-17.

Barros CSL, Fighera R. Babesiosis. In: Foreign animal diseases. 7th edition. Boca Raton, FL: United States Animal Health Association; 2008. p.147-158.

Beaver PC, Jung RC, Cupp EW. Clinical parasitology. 9th ed. Philadelphia: Lea & Febiger; 1984. Family Babesiidae; p. 205-212.

Benavides MV, Sacco AM. Differential *Bos taurus* cattle response to *Babesia bovis* infection. Vet Parasitol. 2007;150:54-64.

Bock R, Jackson L, de Vos A, Jorgensen W. Babesiosis of cattle. Parasitology. 2004;129 Suppl:S247-69.

Cantu A, Ortega-S JA, Mosqueda J, Garcia-Vazquez Z, Henke SE, George JE. Immunologic and molecular identification of *Babesia bovis* and *Babesia bigemina* in free-ranging white-tailed deer in northern Mexico. J Wildl Dis. 2007;43:504-7.

Cho SH, Kim TS, Lee HW, Tsuji M, Ishihara C, Kim JT, Wee SH, Lee CG. Identification of newly isolated *Babesia* parasites from cattle in Korea by using the Bo-RBC-SCID mice. Korean J Parasitol. 2002;40:33-40.

Garner G, Saville P, Fediaevsky A. Manual for the recognition of exotic diseases of livestock: A reference guide for animal health staff [online]. Food and Agriculture Organization of the United Nations [FAO]; 2003. Bovine babesiosis. Available at: http://www.spc.int/rahs/. Accessed 5 Dec 2008.

Gray JS. Identity of the causal agents of human babesiosis in Europe. Int J Med Microbiol. 2006;296 Suppl 40:131-6.

Hunfeld KP, Hildebrandt A, Gray JS. Babesiosis: recent insights into an ancient disease. Int J Parasitol. 2008;38:1219-37.

Liu J, Yin H, Liu G, Guan G, Ma M, Liu A, Liu Z, Li Y, Ren Q, Dang Z, Gao J, Bai Q, Zhao H, Luo J. Discrimination of *Babesia major* and *Babesia ovata* based on ITS1-5.8S-ITS2 region sequences of rRNA gene. Parasitol Res. 2008;102:709-13.

Kahn CM, Line S, editors. The Merck veterinary manual [online]. Whitehouse Station, NJ: Merck and Co; 2006. Bovine babesiosis. Available at: http://www.merckvetmanual.com/mvm/index.jsp?cfile=htm/bc/10402.htm. Accessed 4 Dec 2008.

Karbe E, Grootenhuis JG, Kelley S, Karstad L. Experiments on the *Babesia bigemina* carrier state in East African buffalo and eland. Tropenmed Parasitol. 1979;30:313-7.

Kuttler, K.L. "Bovine Babesiosis." In *Foreign Animal Diseases*. Richmond, VA: United States Animal Health Association. Available at: http://www.vet.uga.edu/vpp/gray_book02/fad/bab.php.* Accessed 4 Dec 2008.

Ohta M, Kawazu S, Terada Y, Kamio T, Tsuji M, Fujisaki K. Experimental transmission of *Babesia ovata* oshimensis n. var. of cattle in Japan by *Haemaphysalis longicornis.* J Vet Med Sci. 1996;58:1153-5.

Queensland Government Department of Primary Industries and Fisheries (DPIF). How to make organ smears. DPIF; 2007 June. Available at: http://www.dpi.qld.gov.au/cps/rde/dpi/hs.xsl/4790_6224_ENA_HTML.htm.* Accessed 4 Dec 2008.

Schmid N, Deplazes P, Hoby S, Ryser-Degiorgis MP, Edelhofer R, Mathis A. *Babesia divergens*-like organisms from free-ranging chamois (*Rupicapra* r. *rupicapra*) and roe deer (*Capreolus* c. *capreolus*) are distinct from *B. divergens* of cattle origin - an epidemiological and molecular genetic investigation. Vet Parasitol. 2008;154:14-20.

Uilenberg G. Babesia--a historical overview. Vet Parasitol. 2006;138:3-10.

Vial HJ, Gorenflot A. Chemotherapy against babesiosis. Vet Parasitol. 2006;138:147-60.

World Organization for Animal Health [OIE]. Manual of diagnostic tests and vaccines [online]. Paris: OIE; 2008. Bovine babesiosis. Available at: http://www.oie.int/eng/normes/mmanual/2008/pdf/2.04.02_BOVINE_BABESIOSIS.pdf.* Accessed 4 Dec 2008.

Zintl A, Mulcahy G, Skerrett HE, Taylor SM, Gray JS. *Babesia divergens*, a bovine blood parasite of veterinary and zoonotic importance. Clin Microbiol Rev. 2003;16:622-36.

*Link defunct as of 2012